STANDARDIZED CONCRETE BRIDGES IN TEXAS

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ABSTRACT

Standardized concrete bridge plans are used extensively by the Texas Department of Transportation (TxDOT). The benefits of using standardized bridges include reduced design effort, widespread implementation of economically proven construction technologies, and reduced construction costs.

This paper details these benefits as experienced by TxDOT, acknowledges limitations of standardized bridge plans, outlines the many concrete bridge systems offered by TxDOT in a standardized format, describes the development process used by TxDOT to create specific standard bridge drawings, and speculates on future standards development.

Keywords: Standardization, Short span, Standard drawings

INTRODUCTION

The Texas Department of Transportation's (TxDOT's) early and consistent use of predesigned bridges has contributed significantly to the quality and size of its bridge inventory. More than 80 percent of Texas' 48,000-plus bridges cross water features, frequently small streams, and more than 90 percent use spans no longer than 120 feet. Simple, short-span bridges are ideal candidates for concrete construction, which produces safe, durable, economical, and aesthetically pleasing structures. Simple, short-span concrete bridges tend to be straightforward and repetitive in design, making their design details ideal candidates for pre-designed, standard drawing formats. Detailed once, plans for these bridges can be used repeatedly, saving engineering time and increasing the level of plan quality.

This paper describes the benefits and limitations of pre-designed standardized bridges, provides a listing and description of standardized concrete bridges offered by TxDOT, outlines a development process for bridge standard drawings, and speculates on future developments with standardized bridges.

BENEFITS OF STANDARDIZED BRIDGE PLANS

Standardized bridge plans have proven beneficial to all stakeholders in Texas' bridge construction program—TxDOT, consulting engineers, fabricators, and contractors. Specific benefits of standardized bridge plans include reduced design costs, reduced construction costs, and widespread implementation of new, improved details.

DESIGN COST SAVINGS

Bridge designers working on a long, straight bridge with uniform span lengths frequently design one element—span, pier, or one bent—and then use it repeatedly in the bridge plans. The same efficiency accrues from reusing design and detailing for common bridges. In Texas, most bridges have the following attributes:

- They have short spans and cross a water feature.
- They are on tangent alignments without severe skew.
- Their spans tend to be a limited number of lengths.
- They represent a limited number of bridge types.
- They have equivalent roadway widths.

Bridge designers can complete the design and details for such bridges once, and then use the same plans repeatedly to build bridges. Over time, this efficiency reaps significant cost savings associated with bridge design.

In TxDOT's experience, the initial effort to produce standardized bridge plans takes twenty to thirty percent longer than the same number of drawings for a custom bridge would require. Once created, maintenance of the drawings is minimal, usually only minor enhancements or corrections unless design specification changes warrant extensive revisions.

CONSTRUCTION COST SAVINGS

Contractors with experience building bridges from standardized bridge plans can prepare more accurate bids and schedules when they find familiar details and know what to expect. In addition, standardized components permit contractors to standardize their own activities such as erecting and bracing beams, grading prestressed deck panels, and constructing formwork.

TxDOT's cast-in-place (CIP) slab and girder spans provide examples of construction cost savings stemming from the use of standardized bridge plans. The steel forms for these structures are have been used for many bridges over the years. If designers selected their own girder dimensions and spacings with such a bridge system, formwork would be a custom effort for every bridge project, driving up costs.

IMPLEMENTATION OF IMPROVED DETAILS

TxDOT has found standardized bridge plans to be a good way to implement improvements to bridge construction details, as shown by its lateral connection of precast double-T beams. TxDOT developed a method to connect flanges of adjacent double-T beams when this bridge system was first standardized in Texas. However, field performance of this system did not meet expectations, and TxDOT funded a research project to improve the method. The research produced a more cost-effective lateral connection detail that is easier to install and performs more durably. TxDOT is currently revising its standard drawings for double-T beam bridges to detail the new connection, and when they are issued, the standard drawings will be used for every double-T beam bridge, effecting instantaneous statewide implementation.

LIMITATIONS OF STANDARDIZED BRIDGE PLANS

Standardized bridge plans take time and resources to prepare and may not be used frequently enough, or at all, to justify this effort. Without a specific need identified, standardized bridge plans should not be developed. Standardized bridge plans also require maintenance, which includes incorporating changes in design or construction specification requirements and addressing poor performing and inadequate details as they are discovered. The standard drawings must be used regularly for maintenance costs to be offset by savings in design process efficiency.

Designers can become too complacent using standard drawings in their plans and neglect to ensure that the details are appropriate for the intended application. Standardized bridge plans have also been criticized for suppressing innovation. This is valid only if the agency providing the drawings does not see the benefit of pursuing new ideas. Standardized bridges may not reflect the latest innovations and ideas, as innovations ideally should be implemented on a trial basis through custom bridge plans. And once new techniques, details, or systems implemented for custom plans prove themselves through performance, a progressive agency can develop them in a standard drawing format.

Some say that standardized bridge plans are a “one-size-fits-all” approach that cannot solve every problem. This is true and it is why standard drawings are most appropriate for common bridge systems.

Standardized bridges are also criticized for their aesthetics. Standardized bridges may not be visually imaginative, but must they be? In Texas, most bridges are built over small stream crossings where a limited rural audience will appreciate aesthetic results. Although engineers should always design good lines into their bridges, the cost of aesthetic enhancement should be weighed against the value set on aesthetics by the bridge users.

TxDOT understands the limitations of standardized bridge plans and recognizes that the need for custom bridge plans. However, standardized bridge plans have been of great benefit to TxDOT in its bridge construction and maintenance programs.

SCOPE OF TxDOT STANDARD DRAWINGS

TxDOT provides standardized bridge plans for six different types of concrete bridges, along with CIP and precast box culverts. These bridges use prestressed I-beams, box beams, slab beams, and double-T beams along with CIP slab spans and slab and girder spans. Drawings cover all superstructure and substructure details. A bridge designer working on a standard bridge always needs to prepare on a bridge layout, which presents overall bridge plan and elevation views, all roadway geometrics, and foundation type and depths. To prepare a bridge layout, a designer must complete a site-specific foundation design based on soil borings and perform a hydraulic analysis if the bridge crosses a water feature. Top-of-cap elevations and beam bearing seat elevations are determined by the contractor based on plan section depths and roadway geometry. In some cases, designers take an extra step and provide these elevations in the plans.

These standardized bridge plans accommodate at least one of TxDOT’s five standard roadway widths—24, 28, 30, 38, and 44 feet. The narrowest three standard roadways are primarily used for bridges off the state’s maintained highway system. In Texas, most insufficient bridges occur off-system, so TxDOT emphasizes standardized bridge plans for these roadways.

Standard drawings accommodate skews to address need and increase scope. All standard concrete bridge types easily accommodate modest skews (less than 45 degrees). With wide precast beam sections (box, slab, and double-T beams), combination of skew and vertical curve requires complex calculations to determine top of cap elevations, as do changes in roadway cross slope. For bridges using wide precast beams, designers take an extra step and provide these elevations in the plans when vertical curves are combined with skew. Changing roadway cross slope is addressed similarly.

A brief summary of available roadway widths, skews, and span ranges for each standardized bridge type is shown in Table 1.

Table 1. Scope of TxDOT Standard Bridge Drawings

TxDOT Standard BridgeType	Number of Available Roadway Widths	Number of Available Skew Angles	Available Span Range
Prestr Conc I-Beams	5	3	30’ thru 115’
Prestr Conc Box Beams	1	1	30’ thru 60’
Prestr Conc Slab Beams	3	3	25’ thru 50’
Prestr Conc Dbl-T Beams	1	1	30’ thru 60’
CIP Slab Spans	5	3	25’ and 30’
CIP Slab & Girder Spans	5	5	30.33’ and 40’

PRESTRESSED CONCRETE I-BEAM BRIDGES

Prestressed concrete I beams are the workhorse of Texas bridge construction. They are the most economical form of bridge construction and are durable. In these standard bridge drawings, TxDOT uses its own beam sections—Types A, B, and C—in conjunction with AASHTO Type IV beams. These beams are 28, 34, 40, and 54 inches deep, respectively. An 8-inch thick slab is used and can be formed conventionally with stay-in-place (SIP) metal forms or with prestressed concrete panels. With few exceptions, contractors select the concrete panels, which are 4 inches thick. Efforts are underway to provide LRFD-based designs for these standardized bridges and to add details to accommodate a 45 degree skew.

Figure 1 Prestressed Concrete I-Beam Bridge

PRESTRESSED CONCRETE BOX BEAM BRIDGES

Prestressed box beams are an excellent solution for bridges demanding shallow superstructures, with span length to depth ratios approaching 30. They are also a good choice when rapid construction is desired.

These are relatively new in a TxDOT standard bridge drawing format, but TxDOT has built many of these bridges based on custom details. Most of the custom bridges use a multi-beam deck system, with beams separated by approximately 1 to 3 inches. A small number have been built in a spread box configuration. The standard drawings are based on the multi-beam system.

TxDOT uses one of its own box beam sections, B20, in both 4 and 5 foot widths. Shear keys between beams are filled with concrete, and the beams are then topped with either a 2-inch minimum asphaltic concrete pavement (ACP) overlay or a 5-inch minimum CIP concrete deck. Transverse post-tensioning is required for beams with the ACP overlay.

TxDOT is currently working on these standard drawings to reflect LRFD-based designs and to increase their scope by two more roadway widths and increased span length with additional beam sections.

PRESTRESSED CONCRETE SLAB BEAM BRIDGES

Prestressed slab beam bridges are much like box beam bridges. They have shallow superstructures and facilitate rapid construction. Standardized bridge details with these beams were developed after TxDOT built many custom slab beam bridges, primarily for bayou and canal crossings along the coast. All these bridges, along with the standardized bridges, use a multi-beam deck system.

These standard drawings reflect LRFD-based designs and use TxDOT's own non-voided slab beam sections, SB12 and SB15. Like box beams, they come in 4- and 5-foot widths. No shear keys or transverse post-tensioning are detailed, and a concrete deck, 5-inch minimum thickness, is required to top the beams.

Figure 2 Prestressed Concrete Slab Beam Bridge

PRESTRESSED CONCRETE DOUBLE-T BEAM BRIDGES

Originally envisioned as a replacement for CIP slab and girder spans, double-T beams are actually used infrequently in Texas. They are deeper than slab and box beams for a given span, but they can be built more rapidly than CIP slab or girder spans.

Like box beams, standard drawings provide for both an ACP overlay and a concrete slab, 2 and 4.5 inches minimum thickness respectively. Beam sections for the ACP overlay bridges are 22, 28, and 36 inches deep and come in 6-, 7-, and 8-foot widths. For bridges with a concrete slab, the top flange of the beam is reduced from 6 to 4.5 inches thick.

TxDOT is now developing “super T” sections with stems 6 inches wider than conventional double-T sections to extend the maximum span of double-T beams. Preliminary calculations indicate that a 90-foot span is achievable with a 36-inch deep “super T” section. Efforts are also underway to reflect LRFD-based designs on the standard drawings.

Figure 3 Prestressed Concrete Double-T Beam Bridge

CIP SLAB SPAN BRIDGES

Of all of TxDOT’s standardized bridges, CIP slab spans have the shallowest superstructure, which is often needed to satisfy hydraulic demands. Limited choices in span length facilitate standardized continuous slabs.

All designs for this standardized bridge system are LRFD-based. Details accommodate al five standard roadway widths and three skews. Slabs are conventionally reinforced and are 14 or 16 inches deep, depending on span length and type, simple or continuous. These are the simplest of all TxDOT’s standardized bridges.

CIP SLAB AND GIRDERS

These standardized bridges are locally called “pan form” bridges due to the shape of their forms. This bridge system was developed in the 1940’s and has been used extensively despite being provided in only two span lengths.

Forms fit between bent caps. Because their length cannot be modified, only two span lengths are detailed, 30.33 and 40 feet, with section depths of 2 and 2.75 feet, respectively. These bridges have unorthodox skew angles, which are a function of form assembly restrictions.

TxDOT is taking steps to provide standard drawings representing LRFD-based designs for this bridge system.

STANDARDIZED BRIDGE PLAN DEVELOPMENT

TxDOT used the following process to develop standard drawings for its standardized CIP slab span bridges. This particular bridge system is useful to all agencies and is a good candidate for standardization. The process demonstrates the steps and level of effort required to provide standard bridge drawings.

1. Identify need.

   TxDOT has numerous county bridges crossing small streams that need replacement as a result of structural inadequacies. Due to the remote location and small scale of these bridges, any bridge system for replacing them must be attractive to small contractors with limited equipment inventories. These locations require a low-cost, short-span bridge system with shallow superstructures to maximize the hydraulic opening.

   CIP concrete slab spans meet these requirements, providing bridges that, although labor-intensive, are especially attractive to small contractors with a labor force they need to keep busy. After assessing these requirements, TxDOT elected to develop standard drawings for CIP concrete slab span bridges.

2. Define scope.

   TxDOT builds county bridges to one of three standard roadway widths—24, 28, or 30 feet. Roadway classification and projected ADT determine which roadway width is selected. For bridges on the state’s maintained highway system, TxDOT provides standard bridge drawings for two other standard roadway widths—38 and 44 feet. As CIP slab spans lend themselves to variable roadway widths, TxDOT elected to develop standard details for all five standard roadway widths to broaden their scope.

   Bridge designers frequently need skewed substructures to fall in line with stream flow. Because CIP slab spans easily handle modest skews, TxDOT decided to provide details accommodating 15 and 30 degree skews.

The easiest scope item to define was span length. Conventionally reinforced CIP slab spans are economical for the shortest spans only; other bridge systems are better when spans exceed 30 feet. TxDOT chose two- and three-span continuous slabs with each span at 25 feet, a three-span continuous slab with a 25-30-25-foot configuration, and a 25 foot simple span.

TxDOT selected drilled shafts for the foundations because they are the predominant bridge foundation in Texas, offering trestle piling as a foundation option.

3. Define design criteria.

   TxDOT developed design criteria that included design specifications, material properties, geometry and member proportions, and detailing requirements.

   TxDOT historically has prepared its own standard bridge drawings; however, in the past few years it has successfully used the services of consulting engineers to prepare standard drawings. For the CIP slab span bridges, TxDOT provided design criteria and scope of work and then contracted with a consulting engineer—Chiang, Patel, and Yerby, Inc.—to design and detail these structures.

4. Design, detail, and review.

   For CIP concrete slab span bridges, a total of 90 standard bridge drawings that cover five roadway widths, three skew angles, four span configurations, and two foundation types were produced. This task required more staff hours than producing 90 bridge drawings for a custom bridge would have primarily because it demanded more in-depth review.

FUTURE DIRECTIONS IN TxDOT STANDARDIZED BRIDGES

Standardized bridge plans have historically provided for conventional construction techniques, and aesthetic concerns have been minimized. In the future, TxDOT will take steps to incorporate rapid construction techniques as an option to conventional construction practices. Along with this effort, TxDOT will explore simple, aesthetic treatments that can be standardized.

RAPID CONSTRUCTION

As a proponent of rapid bridge construction technologies, TxDOT will implement optional precast bent caps with standardized bridge details. TxDOT has proven that precast bent cap technology has matured sufficiently to allow its implementation in a standardized format.

As currently envisioned, this implementation will take place as an option allowing contractors to substitute a CIP bent cap with a precast version. Precast caps will have the same flexural and shear reinforcement as CIP caps and have additional details outlining the connection to columns. If this initial effort to incorporate rapid construction practices proves successful, TxDOT will explore use of other precast bridge elements.

AESTHETICS

As an enhancement to its standardized bridge details, TxDOT is studying alternative column geometries and form-liner configurations that can be used as an option to the traditional, smooth round columns used in standardized and custom bridge details. For short-span bridges, round columns have proven to be the most economical column in Texas, but their aesthetic value is questionable.

TxDOT plans to offer a designer or owner multiple column geometries, with or without form liners, as options that will work with no modification to the standard column reinforcement detailed. Obviously, any aesthetic enhancement will be subtle, but some of the best bridge aesthetics involve simple and modest details.

SUMMARY

Standardized concrete bridge plans have proven instrumental in the success TxDOT has experienced in its bridge construction program. These plans meet a great need for simple, short-span bridges, and concrete bridge systems are very adaptable to standardization.